4 METHODS

The survey methods used for this project were designed to provide a set of standardized, repeatable measurements consistent with those reported in a previous habitat survey of the Middle Green River (R2 Resource Consultants 2002). However, unlike the scope of this previous survey, which examined off channel habitats in addition to the mainstem river, the data collected in this present study were gathered almost entirely from the water levelalong the mainstem river. This approach was taken in the Lower Green River because the riverbanks in many areas were high, quite steep, and often overgrown with blackberries. As a result, the banks and riparian areas landward of the top of the bank were inaccessible to the boat-mounted field crew. Quality assurance and quality control (QA/QC) measures were implemented to ensure the repeatability of the methods and the accuracy of the results. The results of this survey provide a basis for making comparisons to past or future conditions, as well as for drawing conclusions about existing habitat quality parameters at the reach scale. The following sections describe the project approach, sampling methods, QA/QC measures, and the data management approach taken.

4.1 Project Approach

The survey approach was designed to be as consistent as practicable with previous studies of other reaches of the Green River, specifically the *Green River Baseline Habitat Monitoring 2001 Data Report* (R2 Resource Consultants 2002) that documented instream habitat conditions in the Middle Green River from RM 64.5 to RM 32.1. Consistency of methods and datasets between the Lower and Middle Green Rivers studies is important for providing a directly comparable characterization of a broad expanse of the Green River. To this end, the following study design drew heavily from 2002 study.

4.1.1 Stratification of the Study Area

Prior to the field investigation, the study area was subdivided into five study reaches. The reach divisions were determined based on similarity of gradient and sinuosity, and, to a lesser extent, local jurisdiction borders. Gradient and sinuosity information provided in Kerwin and Nelson (2000) was used in this stratification. The study reaches were delineated as shown in Table 4-1 and Figure 2-1. Reaches and stations were numbered in increasing order moving downstream.

Table 4-1
Study Reaches used in Lower Green River Habitat Survey

Study Reach	River Miles	Gradient	Sinuousity	Municipality
1	32.1 to 26.6	1 percent to 2 percent	Low	Auburn and unincorporated King County
2	26.6 to 19.1	<1 percent	Moderate	Kent
3	19.1 to 15.6	<1 percent	Low	Kent
4	15.6 to 11.2	<1 percent	Moderate	Tukwila
5	11.2 to 5.7	<1 percent	Low	Tukwila

4.1.2 Field Crews

Field surveys were conducted by three individuals: John Small, Anchor (all study reaches); Chip Maney, Parametrix (Reaches 1 through 3); and Kathryn Gellenbeck, WRIA 9 (Reaches 4 and 5). On any given day, two of these individuals worked in a two-person team. The team traveled in two kayaks or in a canoe and a kayak. All data were collected from the sampling vessel or shore, and pertained only to features that were in the line of sight from the water's edge.

4.1.3 Key Survey Parameters (Station-Specific)

Stations were established at 300 meter (m) intervals using a laser rangefinder (Bushnell Yardage Pro 500, Bushnell Yardage Pro 1000, or Sonin Multi Measure Combo Pro). Differential Global Positioning System (DGPS) location information and all other data were recorded using a Trimble Pathfinder Pro TSC1 data logger and field notebooks. At each station, information on the parameters described in the following sections was recorded. For the collection of data that required separate classification for each bank, the left and right banks were always designated from a downstream-facing orientation. The parameters are a combination of those measured at each station (e.g., wetted width), and those characterizing the 300 m segment between stations (e.g., woody debris counts). For those parameters that characterize the entire 300 m segment between stations, the field crew evaluated conditions as they moved downstream from one station to the next. The data for these parameters were entered into the DGPS at the downstream end (station) of the 300 m segment, and therefore characterize habitat conditions in the 300 m immediately upstream of the station.

4.1.3.1 Habitat Type

The original data dictionary for the project included the following habitat type classifications (per Armantrout 1998): glide, run, riffle, pool, backwater, and cascade; however, there were no cascades within the study area. Pools were distinguished by the presence of a longitudinally concave streambed. Glides and riffles were distinguished from one another by surface turbulence. Glides were identified in shallow areas without surface turbulence and riffles were identified as shallow areas with small ripples of surface turbulence. Runs were distinguished as deeper areas with fast moving water and a lack of notable surface turbulence.

4.1.3.2 Bankfull Width / Ordinary High Water Mark Width

Given the confined condition of the study area, traditional measurement of bankfull width (i.e., the distance between the tops of the most pronounced banks on either side of a stream reach [Armantrout 1998]) was determined to be an artificial measure. Therefore, for the purposes of this study, the bankfull width in channel segments confined by levees and/or revetments was considered to be the width between the Ordinary High Water mark (OHWM) on either bank. Wherever possible, the OHWM was determined as the lowermost vertical extent of terrestrial woody vegetation. In locations where vegetation was absent, water marks and drift lines were used. This measurement was taken at each station.

4.1.3.3 Wetted Width

Wetted width was measured at each station to the nearest foot using one of two methods and converted to meters. When using the acoustic rangefinder both the transceiver and target were held 1 m above the wetted edge on opposite banks of the river. In situations when the laser rangefinder was used, range distances were taken from a boat positioned at the water line on one bank to the waterward side of a boat on the opposite bank, or to a rock or bare earth target. Estimates were made of any necessary correction to the measurement to account for any offset from the wetted edge.

4.1.3.4 Woody Debris

Woody debris in each of seven classes was counted as the field crew moved downstream from one station to the next, and totals were recorded every 300 m. The classes were based on Timber Fish and Wildlife level 1 protocols appropriate for extensive reach-based efforts (R2 Resource Consultants 2002). Wood pieces were classified and counted according to size and presence of a rootwad using the following size classes:

Key piece:	Greater than 85 cm diameter and at least 10 m in length
Key piece with rootwad:	Greater than 85 cm diameter, at least 10 m in length, and including a rootwad
Large log:	≥50 cm diameter along at least 2 m of its length and not a key piece
Large log with rootwad:	≥50 cm diameter along at least 2 m of its length, not a key piece, and including a rootwad
Medium log:	30.5 cm to 50 cm diameter along at least 2 m of its length
Medium log with rootwad:	30.5 cm to 50 cm diameter along at least 2 m of its length and including a rootwad
Rootwads:	Without a qualifying log attached, but at least 2 m in diameter

Key pieces are individual logs that are less likely to move in bankfull flow conditions. Perkins (1999) estimated that the minimum size of a key piece of woody debris in the mainstem Green River is 85 cm in diameter and at least 10 m long. As with the R2 Resource Consultants (2002) study, a separate record of small logs (i.e., individual pieces with a diameter smaller than 30.5 cm) was not taken, except those contributing to a qualifying jam (10 or more pieces of wood) (see Section 4.1.4.2). Individual small logs that are not incorporated into a jam are unlikely to remain stable in the channel or influence channel morphology.

4.1.3.5 Bank Type

The primary bank type along the left and right banks of each 300 m segment were observed by the field crew as they moved between stations. The data were recorded at the station marking the downstream end of the segment. Each bank was classified as either natural or as a levee/dike/revetment. Typically, levees can be distinguished from revetments by the presence of raised fill composing the crest of the facility and lower ground surface elevation landward of the facility compared to the surface elevation of the facility itself. However, these flood control facility classifications could not be differentiated from the water surface because the ground surface landward of the top of bank was not visible from the water. Specific information flood control facilities within GRFCZD, which extends from RM 6.50 to 33.85, is currently available from King County and are included on the results figures. In many cases, there was little physical evidence indicating whether unarmored banks were unnaturally confining. In most cases, the percentage of shoreline armor was a better indication of channel confinement.

4.1.3.6 Bank Height

At each station, two measurements were recorded to calculate a rough estimate of bank height. First, a distance (*d*) was taken across the channel to the opposite bank at about OHWM height. Second, the angle (*a*) was measured using a handheld clinometer (Suunto model KB-4; Photo 4-1). Once completed, the bank height (*x*) was estimated using the formula $x = d * \text{Tan}a$. This method did not account for bank slope. Due the difficulty of obtaining distance readings to the top of bank through thick vegetation, it was not possible to measure the distance to the top of the bank which would have allowed for a better estimate of bank height.

Photo 4-1. Estimation of bank height using clinometer.

4.1.3.7 Shoreline Armoring

A visual estimate of the percentage of bank armoring and dominant armor type along each 300 m reach was recorded. The dominant armor types were: riprap, sheetpile, bulkhead, and other. Examples of other types of armor included tires, broken concrete, bricks, and trash. Separate estimates were made for each bank based on the 300 m immediately upstream from the recording station. Additionally, separate DGPS location data were recorded to document the presence of unusual structures functioning as bank armor, such as tires or refuse (Photo 4-2). Due to obscuration of bank armor in numerous locations by sediment deposits and vegetation, these are conservative estimates and may underestimate the full extent of bank armor.

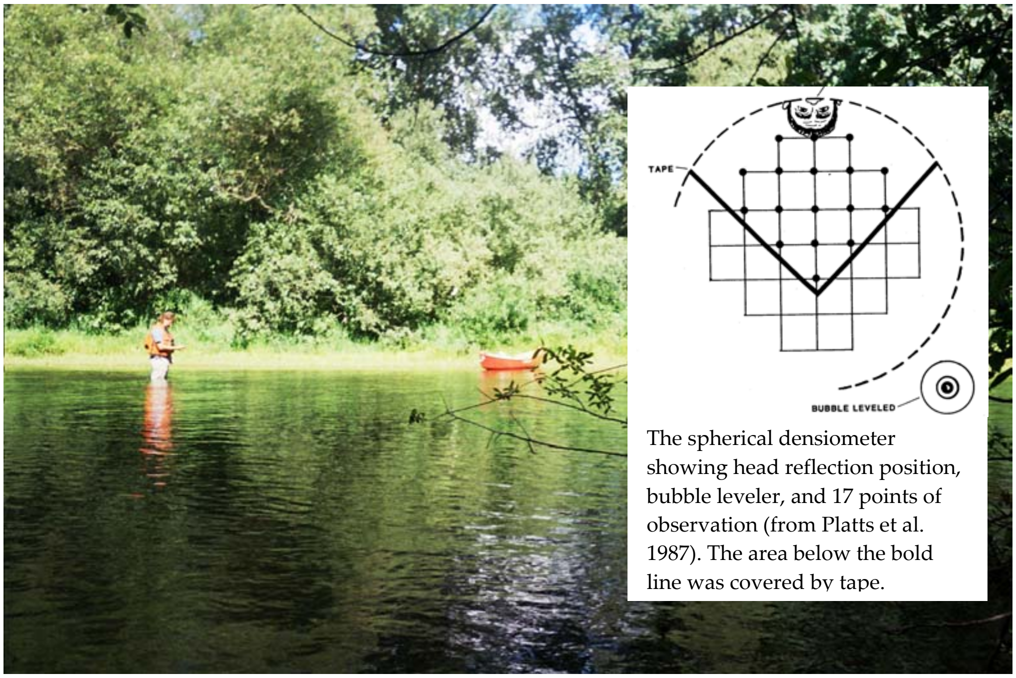
Photo 4-2. Concrete, tire, and other debris on a bank of the Lower Green River.

4.1.3.8 Canopy Cover

Canopy cover was measured at each station using a modified densiometer. The densiometer was modified to use only 17 intersections of the mirror grid by taping off the SE and SW sectors (N at top of mirror; Strickler 1959l; Photo 4-3). This method reduces the measurement of trees and other plants in the mid- to distant-foreground, which can lead to an overestimate of the vertical canopy cover. This modification of the densiometer concentrates on trees and shrubs that are more overhead and representative of actual cover.

Four densiometer measurements were collected using a protocol developed by the U.S. Forest Service (Platts et al. 1987). One measurement was taken at the left-bank edge of water while facing toward the bank. Two measurements were taken at mid-channel, one while facing upstream and the other while facing downstream. The fourth measurement was taken at the right-bank edge of water while facing toward the bank.

To calculate percent canopy cover, the four measurements were added together and multiplied by 1.5. Then, one percent was deducted from scores between 30 and 65 percent, and two percent was deducted from those scores over 65 percent. No deduction was made for scores less than 30 percent (Platts et al. 1987).



The spherical densiometer showing head reflection position, bubble leveler, and 17 points of observation (from Platts et al. 1987). The area below the bold line was covered by tape.

Photo 4-3. Preparing to measure canopy cover using modified densiometer.

4.1.3.9 Riparian Vegetation Type

Field crews visually estimated the dominant riparian vegetation type on each bank based on the vegetation from top of bank to the edge of water for the entire 300 m upstream of each station location. Left and right bank vegetative conditions were classified separately. The following categories and definitions were used in this characterization.

- Immature native vegetation/restoration plantings – sparse vegetation that overhangs the wetted channel by less than 3 m (10 feet)
- Mature overhanging native vegetation – trees and/or dense native shrubs that overhang the wetted channel by more than 3 m (10 feet)
- Invasives – particularly blackberries and reed canarygrass
- Landscaped/mowed vegetation
- Other vegetation
- Unvegetated

The category "immature native" was generally reserved for recent restoration plantings (less than three years) as no recent natural colonization of native species were dominant.

4.1.3.10 Overhanging Vegetation

A visual estimate was made of the percentage of each 300 m of bank upstream of each station that where vegetation extended beyond the edge of the OHWM by at least 3 m (10 feet) horizontally. All strata of vegetation were considered, including tree canopy high above the water.

4.1.3.11 Riparian Vegetation Quality

Riparian vegetation quality was estimated for the entire 300 m section between stations. Separate estimates were made for left bank and right bank conditions using three categories: high, medium and low. Low quality was used to indicate areas with few or no trees and at least 80 percent total cover by grasses and invasive shrub species; medium quality was used to characterize banks with mixed native and invasive shrubs and scattered trees (less than 80 percent total coverage of native species), generally set back from the edge of water. High quality was used to describe banks with large native trees and dominated by native species (at least 80 percent total coverage of native species).

4.1.3.12 Docks and Piers

The presence and number of docks wider than 2.5 m (8 feet) located within 300 m upstream on either bank was recorded at each station.

4.1.3.13 Additional Comments

Any miscellaneous comments were also recorded.

4.1.4 Non-Station Specific Parameters

In addition to the station-specific parameters collected at the 300 m interval stations, information on the following non-station specific parameters was recorded. This allowed for the accurate recording of the DGPS location of each feature of interest.

4.1.4.1 Pools

Pools were visually identified and were defined as areas with a concave profile parallel to the flow direction that comprised 25 percent or more of the OHWM width. The location of the upstream end of each pool was recorded using the DGPS unit. Pool widths were measured using a laser rangefinder, an acoustic rangefinder, or by visual estimate. Two classes of pools were identified: small pools, with an estimated width between 25 percent and 50 percent of the OHWM width; and large pools with a width greater than 50 percent of OHWM width. No attributes other than location were recorded for the small pools. The following additional attributes were recorded at all large pools:

- Estimated length: typically measured with a laser rangefinder
- Maximum depth: as measured with a weighted line, marked kayak paddle, or acoustic depth sounder (the depth sounder was used in Reaches 4 and 5 data on October 25 only)
- Average width: this was calculated as the average width of a series of widths at approximately equal spatial intervals
- Minimum riffle crest height at thalweg: this was measured with a marked kayak paddle
- Dominant pool forming factor(s): Woody debris, bedrock, bridge abutments, riprap and other/unknown.
- Pool type (per Armantrout 1998): lateral scour, mid-channel scour, or plunge
- Photographs of each pool type were taken

Using these data, summary statistics of pool occurrence were calculated for the total number of pools, as well as separately for large pools and small pools. The frequency of pools was calculated relative to the OHWM channel width (CW) meters using the following equation:

Frequency of pools = [(Reach length in meters) / (CW)] / (Number of pools)

This equation gives pool frequency in units of the number of CW per pool. This calculation was based on "unrounded" numeric results; therefore direct calculation from rounded numbers in the reach summary tables may provide different results.

Pool frequency per mile was calculated by dividing the number of pools in a reach by the reach length (in miles). The percentage of reach length and area were calculated for large pools. The percentage of the reach length covered by large pools was calculated by summing the lengths of all large pools identified and dividing by the reach length in meters.

The percentage of the reach area covered by large pools required the following steps. First, the areas (m^2) of all pools in the reach were summed. Next, this sum was then divided by the area of the reach in meters. The area of the reach was calculated by multiplying the length of the reach in meters times CW in meters.

4.1.4.2 Debris Jams

Debris jams with 10 or more wood pieces were counted in each reach and the locations recorded using DGPS. Debris jams were categorized by size, with counts including small (less than 30.5 cm diameter), medium, large, and key woody debris pieces:

- Small jam: 10 to 50 pieces
- Medium jam: 50 to 100 pieces
- Large jam: more than 100 pieces

4.1.4.3 Gravel Storage Areas

Existing and potential gravel storage areas were noted and their upstream and downstream margins recorded using DGPS. Existing gravel storage areas consisted of gravel bars, substantial pool tailouts, and channel margin deposits. Potential gravel storage areas were defined, for the purposes of this study, as areas where gravel could be stored in the channel if the river were not anthropogenically altered.

4.1.4.4 High Quality Habitat and Potential Restoration Sites

Habitat restoration and conservation opportunities were identified during the field survey and from aerial photography. The locations of those areas identified during the field survey were recorded using DGPS. Most restoration and conservation opportunities were identified at the end of the field day by combining impressions from the river with observations of the aerial photography. This allowed the team to expand their considerations beyond the channel and adjacent riparian zone to the adjacent floodplain.

Observations were made of areas of relatively high quality habitat for salmonids and other native aquatic species. Areas where restoration of the channel, banks or immediately adjacent floodplain would provide definite improvements to habitat were also noted. DGPS location data were recorded at the upstream and downstream end of sites identified from the water. Additional sites were identified at the end of each day as the field crews planned subsequent work using aerial photography. This provided an opportunity to combine field observations with an understanding of land uses beyond the top of the river's banks. These observations are shown in the figures in Section 5. Potential off-channel restoration opportunities were not addressed in this study.

4.1.4.5 Outfalls

The locations of all outfalls exceeding 30 cm in diameter were collected from the approximate edge of water. The parameters recorded included the diameter of the outfall and the presence or absence of a flapgate, a structure that prevents flow from the river from entering the outfall structure (Photo 4-4) during floods.

Photo 4-4. Outfall with flapgate in a bank of the Lower Green River.

4.1.4.6 Invasive species

Observations were recorded on the locations of two invasive vegetation species: Japanese knotweed (*Polygonum cuspidatum*) and purple loosestrife (*Lythrum salicaria* L.) in the study area (Photo 4-5 and 4-6, respectively). DGPS locations were recorded where a patch of either species was noted in the area from the edge of water to the top of bank. Positions were taken at the approximate longitudinal center of each patch from the edge of water. The length of each patch along the shoreline was also estimated.

Photo 4-5. Japanese knotweed lining the bank of the Lower Green River.

Photo 4-6. Purple loosestrife in the survey area (tall flowering plant directly behind field crew member).

4.1.4.7 Pilings

The locations of groups of pilings were documented using the DGPS unit and the total number in each group was recorded.

4.1.4.8 Additional Points of Interest

Additional DGPS points and information were recorded for several points of interest along the study area, including the locations of tire revetments, submerged cars, water withdrawal pipes, and other unusual features.

4.2 Data Management, Export and Analysis

The DGPS data files were differentially corrected in real time or using post processing techniques, and exported in ESRI Shapefile format. Additional data edits were then made to reflect either digital or field book notes taken during data collection.

Data collected on September 26, 2003 were lost when the DGPS TSC1 data collector failed. During this day, data had been collected within Reach 4 at Stations 22 through 24, and within Reach 5 at Stations 1 through 9. Field crews were unable to repeat the survey until October 25, 2003 when the river's discharge had increased and water clarity had diminished, precluding the measurement of some of the key parameters. Therefore, some data were recreated manually using hand-written field notes, and other data were re-collected in the field. Original field book data were used to re-create some information for Reach 4, Stations 22 through 24, and Reach 5, Stations 1 through 9. Additionally, these station locations were reset at equal intervals along the river to fill the gap between Reach 4, station 21 and Reach 5, station 10. A field crew (John Small, Anchor, and Ruth Schaefer, King County Water and Land Resources Division) re-gathered information on pools, pilings, invasive species and other non-station-specific survey parameters; the same equipment and protocols were used for this re-collection of data.

4.3 Quality Assurance/Quality Control

QA/QC is integral to the reliability of the results of this survey project. Measures were taken to include QA/QC in multiple steps of the survey effort:

- **Equipment calibration.** Equipment was checked daily for consistency in the field before the commencement of field sampling.

- **Data categorization.** Field crews checked categorizations against one another on a daily basis to standardize determinations for categorical variables.
- **Data entry QA/QC.** Data were checked for accuracy after downloading from the field logger. After import into data analysis tools, digital data were checked against field logs if discrepancies were noted.
- **Repeat surveys.** Reach 1, Stations 1 through 8, and Reach 2, Stations 1 through 6 were repeated and used for QA/QC purposes. Comparing the repeat surveys revealed that on average, channel width measurements were typically within 1 m to 2 m of one another, log counts were within approximately 0.2 to 0.6 log, overhanging vegetation estimates were within 1 to 15 percent, and other variables were counted identically between 70 percent and 100 percent of the time.